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Technical Report 708

# PORTABLE AIR DRIVEN VARIABLE SPEED FIBER OPTIC CABLE TERMINATION POLISHER

A. Flores

15 March 1981

Prepared for
Naval Air Systems Command

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## ADMINISTRATIVE INFORMATION

The Naval Ocean Systems Center (NOSC) was tasked by the Naval Air Systems Command, under the Navy Manufacturing Technology Program, to establish manufacturing methods in industry to assure the ability to produce, on a volume basis, a portable air driven variable speed fiber optic (F.O.) cable terminal polisher. The polisher possesses the characteristics necessary to perform in the operational environments encountered during the installation and maintenance of fiber optic cables in military aircraft.

This project was satisfactorily accomplished under contract (N66001-78-C-0035) to the ITT, Cannon Electric Division in Santa Ana, California. The delivered polishers are presently being field tested to assess their applicability and effectiveness for their intended purpose.


## ACKNOWLEDGEMENT

The author wishes to acknowledge the efforts of ITT Cannon personnel C. H. Stevens and S. Levasheff for the development of the polisher and NOSC personnel G. Kosmos, G. Holma and D. Forman for their contributions towards the satisfactory accomplishment of the program.


Released by
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Design Engineering Division

Under authority of
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Electronics Engineering and
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Manufacturing processes and techniques were developed to produce in larger volume a portable air driven variable speed fiber optic cable polisher with the necessary characteristics to perform in the operational environments encountered during installation and maintenance of fiber optic cables in military aircraft.

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A

## 1.0 INTRODUCTION

The Naval Ocean Systems Center, Code 9242, was tasked to establish a manufacturing technology program (MTP) to develop or improve manufacturing techniques, processes, materials and equipment to provide for timely, reliable and economical production of defense material applicable to implementation of fiber optic technology of military systems.

Structured to bridge the gap between emerging research and development technology (R&D), and full scale economical production of military equipment, the MTP projects are undertaken only after concept feasibility has been proven and high potential applicability has been demonstrated.

The MT program strives to ensure that the output of established R&D programs can be implemented into operational military systems at reduced manufacturing and life cycle costs of defense material.

This final report outlines the work performed by NOSC, Design Engineering Division personnel (Code 9242) and the ITT contractor, to establish the necessary manufacturing processes to develop a variable speed air driven fiber optic cable polisher for use during installation and maintenance of fiber optic cables in military aircraft.

## 2.0 BACKGROUND

It has been demonstrated in the A-7 Airborne Light Optical Fiber Technology (ALOFT) program that fiber optics can be successfully used on military aircraft. The many advantages of a multiplexed, fiber optic data interface--such as immunity to EMI (electromagnetic interference), EMP (electromagnetic pulse), and lightning strikes; reduced systems weight; and reduced complexity in external harnesses and connectors, resulting in improved reliability and maintainability--have also been demonstrated. Before fiber optics can be used on a production aircraft, support equipment and components must be developed in order to adequately install and maintain fiber optic systems aboard military aircraft.

At the present time, enough support equipment and components have been developed such that serious consideration can be given to the implementation of fiber optic systems in military platforms.

Fiber optics has progressed from research and development to feasibility demonstrations, it has become apparent that planning for high volume production of fiber optic components is necessary. Questions of production compatibility, applicability, and cost are addressed under this contract in order to identify and correct problems associated with the installation of fiber optics aboard military aircraft.

## 3.0 MAJOR DEVELOPMENT OBJECTIVES

All development efforts were directed toward obtaining methods to produce a durable and ruggedized portable F.O. cable terminal polisher which will endure the field environment encountered in normal maintenance operations for military aircraft avionic systems.

Special emphasis was placed on manufacturing techniques which will produce polishing equipment that shall guarantee a termination end finish with maximum roughness of 10 micro-inches and a maximum finish waviness of .001 inch over the entire surface end of the termination as defined in USAS B 46.1.

Another major objective of this effort was to develop manufacturing methods to produce a terminal polisher which is easy to operate and maintain and has the ruggedness characteristics required to achieve an expected service life of 10 years.

A fiber optic cable terminal polisher which has the capability to terminate a multiplicity of F.O. cables of different diameters and different end ferrule configurations, can be provided by adapting different collets to the particular ferrule configurations.

Since the termination process for fiber optic cables requires wet polishing techniques, the polisher provides, as an integral part of the design, a capability for dispensing the wetting fluid and a means for collecting and disposing of slurry. Of particular importance is the relationship of the cable holding mechanism to the polishing surface. The cable holding mechanism holds the end termination perpendicular to the grinding or polishing surface with a repeatability of setting necessary to comply with the maximum waviness requirement of .001 inch.

## 4.0 EQUIPMENT DESCRIPTION

As previously stated, the objective of Contract N66001-78-C-0035 was to develop fiber optic terminal polishers, and the manufacturing methods to produce them on a volume basis. The polishers must perform in the environments encountered during installation and maintenance of fiber optic cables on military aircraft. The development requirements were as follows:

A. The polisher(s) must be simple to operate, variable speed, air driven and portable for military flight line maintenance.

B. Manufacturing methods must be developed to produce the polishing equipment that will guarantee termination finishes with a maximum roughness of 10 micro-inches and maximum waviness of .001 inch.

C. A miniature polisher must be developed to facilitate F.O. cable repair onboard military aircraft. The head must be small enough to fit into a three-inch cube.

D. The polishers must be easy to maintain and designed for a 10-year life.

Two polishers were developed by ITT Cannon Electric specifically to meet the contractual requirements of N66001-78-C-0035. One is called the terminal polisher and the other is the miniature polisher head accessory.

The terminal polisher is a free-standing, bench-top unit (See Figure 1). It consists of five major components as follows:

1. Variable speed pneumatic drive motor
2. Spindle housing assembly
3. Grinding/polishing wheels
4. Slurry container/stand
5. Collet and collet arm

In order to meet the finish and waviness requirements, a .001 inch run-out tolerance is maintained between the spindle bearing bores in the housing and

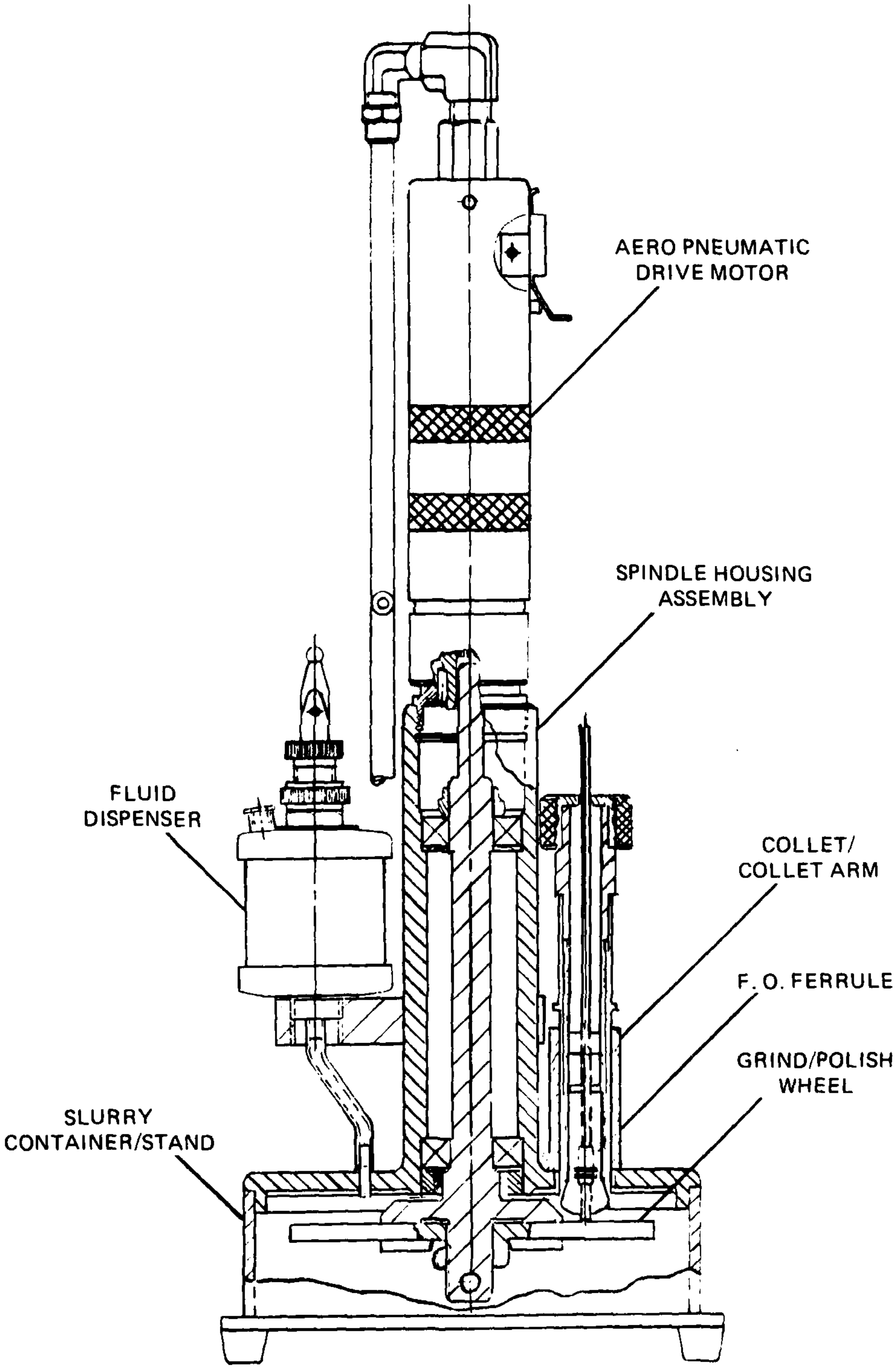


Figure 1. F. O. terminal polisher.

the collet arm mounting surface. A .0005 run-out tolerance is also maintained between the spindle bearing surfaces and the grinding/polishing wheel mounting surface. Consequently, the grinding/polishing surface is established to run true to the collet and thus the F. O. ferrule end.

The polisher configuration incorporates a sealed spindle above the grind/polish surface to minimize bearing contamination, and thus meet the 10-year design life.

The miniature polisher head accessory is a hand-held unit. It has been designed as an accessory, to be mounted on the same aero-drive motor used with the terminal polisher. It consists of six major components as follows (See Figure 2):

1. Aero right angle gearhead
2. Housing
3. Eccentric driver/spindle
4. Adjustable collet
5. Grind/polish wheel
6. Housing cap

Precision tolerances are required between the thrust bearing surface and the collet axis. The grinding wheel is loaded against the thrust bearing in order to establish the wheel to collet location, and thus meet the finish and waviness requirements. The grinding and polishing wheels are driven through an eccentric, thus causing a cycloidal grinding action on the ferrule end. Consequently, the ferrule is fixed in place and the wheel(s) moves, allowing the unit to be used in the tight confines of military aircraft.

In order to meet the contract environmental conditions, all components for both polishers were either specified to be fabricated from, or finished with, corrosion resistant materials.

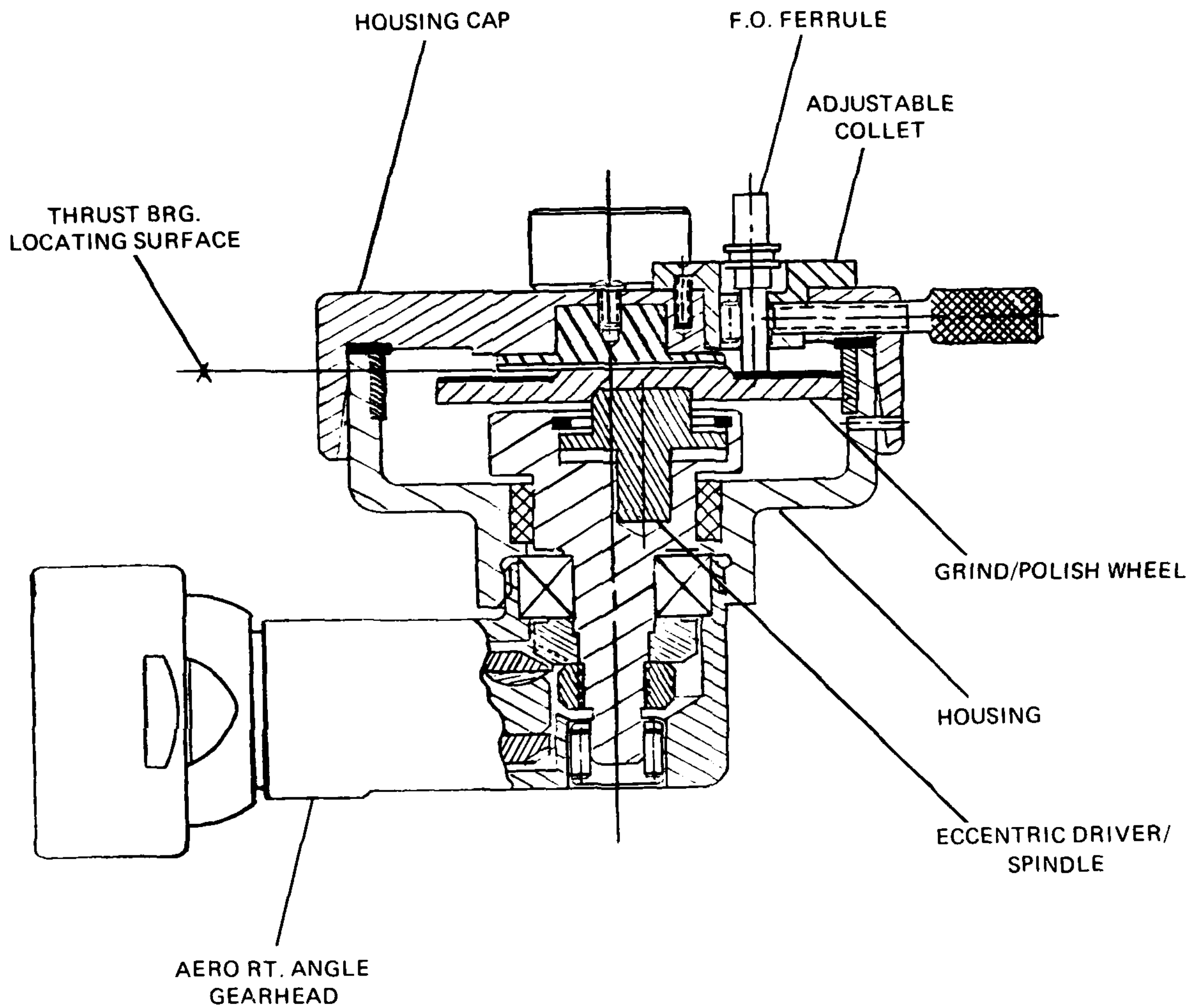


Figure 2. Miniature polishing head accessory.

The prototype polishers were fabricated and tested to the contract requirements. All requirements have been successfully satisfied. Terminations made with ferrules polished on these tools have been measured with less than 3 dB loss. The major contract objectives, of a surface finish of 10 micro-inch and a waviness of less than .001 inch, were exceeded.

Two micro-inch and .0005 inch waviness measurements have been consistently attained; thus, the objectives of this contract are considered to have been satisfactorily accomplished.

## 5.0 OPERATION

Because of the fire hazards encountered inside aircraft hangars and aircraft maintenance facilities such as in aircraft carriers, air-driven maintenance equipment is preferred over electrically-driven equipment. It was for this reason that a pneumatically operated polisher was developed. The only requirement for operation of the polisher is the availability of a 100 psi dry air supply which in remote applications could be provided by air bottles.

The terminal polisher, bench model, is operated as follows:

1. Connect it to a suitable 100 psi dry air supply. Fill the pneumatic lubricator with high-grade light turbine oil (5 or 10 Wt.).

2. Install the 1500 mesh diamond grinding wheel.

3. Place the spindle on the base and retain with the clips.

4. Fill the fluid dispenser with water and lift the lever to start the flow. The flow rate is adjustable, and should be adjusted to saturate the rotating grinding wheel.

5. Remove the collet from the collet arm. Insert the ferrule into the collet until it bottoms on the inside of the collet. Tighten the collet knob to clamp the ferrule in place. The tip of the ferrule should now be protruding from the face of the collet.

6. Switch the air motor on.

7. Carefully insert the collet into the collet arm, until the ferrule contacts the grinding wheel. DO NOT impact the wheel as the fiber(s) may be shattered.

8. Proceed with grinding by slowly moving the collet arm across the entire face of the grinding wheel, until the entire face of the ferrule end is flat.

9. Remove the collet-ferrule assembly intact, and thoroughly clean all grinding residue from the collet and ferrule end.

10. Turn the air motor off. Remove the spindle from the base and remove the diamond grinding wheel. Clean the spindle and wheel mounting surface. CAUTION: If all the diamond grinding residue is not removed, the lap will become contaminated and damaged.

11. Install the lapping wheel and repeat Step 3 above.

12. Switch the air motor on.

13. Charge the lap with Linde A, saturate the surface, through the hole provided in the spindle housing.

14. Repeat Step 7 above.

15. Proceed with lapping until a scratch-free mirror finish is attained.

16. Grind and polishing RPM: 215-230 factory set.

17. Remove the polished ferrule from the collet assembly. Carefully clean all equipment with water and dry prior to storing.

The miniature polisher head accessory is operated as follows:

1. Assemble the miniature polisher head to the air motor, and connect the motor to a suitable 100 psi dry air supply. Fill the pneumatic lubricator with high-grade light turbine oil (5 or 10 Wt.).

2. Remove the housing cap and install the grinding wheel on the eccentric driver.

3. Replace the cap.

4. Remove the filler plug and flood the cavity with water. Replace the plug.

5. Size the adjustable collet for a snug slip fit on the ferrule to be polished as follows: insert the ferrule into the collet and adjust the knurled screw until the ferrule slides in the collet without rocking.

6. Switch the air motor on, and switch the pneumatic speed control to the high speed setting. The spindle RPM should be 300 RPM.

7. Insert the ferrule into the collet and proceed to grind by applying light axial pressure on the ferrule. Grind until a flat surface is obtained across the entire ferrule surface.

8. Remove the ferrule and turn off the air motor.

9. Remove the housing cap and the diamond grinding wheel. Thoroughly clean all grinding residue from the ferrule, cap and housing. CAUTION: if all residue is not removed, the lap will become contaminated and thus be damaged.

10. Install the lap wheel and the cap. Charge the lap with Linde A through the filler plug opening.

11. Switch the motor on.

12. Insert the ferrule into the collet and proceed to lap the surface until a scratch-free mirror finish is achieved.

13. Turn the motor off and thoroughly clean all components with water. Dry prior to storing.

## 6.0 DELIVERABLES

All deliverables as originally established in Section H of the contract and subsequently modified and accepted by NOSC, have been delivered and in conjunction they comprise the manufacturing and production documentation package necessary to produce the termination polishers.

The deliverables of the contract consisted of one complete set of documents including a complete set of manufacturing drawings per MIL-SPEC-1000, an actual cost analysis study, quality assurance procedures and five (5) polisher sets.

## 7.0 COST ANALYSIS

This cost analysis represents an effort to identify the associated costs of manufacturing a fiber optic cable termination polisher as per contract N66001-78-C-0035.

The analysis is based upon actual cost factors involved in a full production run of ten (10) units and includes materials, fabrication and manufacturing processes, quality assurance procedures and other costs incurred in the actual production of ten (10) units.

Since there is no basis for a cost comparison study, this report only attempts to identify the high cost factors that may be improved when large production runs are attempted.

Cost factors analyzed for this study include:

- Materials
- Production set up costs
  - Tooling
  - Facilities & Equipment
- Special handling and processing
- Assembly time
- Fabrication and manufacturing
- Quality control
- Overhead
- Test equipment

and conforms to the following:

1. Report, Cost Analysis per UDI-F-111 dated 18 February 1977, Pages 1 and 2, Addressing Factors 10.1 thru 10.12.

2. Low-Volume, less than 25 units per year, fabrication techniques commonly used in a job-shop type machine shop.

3. All fabrication and assembly costs are based upon a shop rate of $20.00 per hour, split 40% labor and 60% burden.

4. All costs are for one (1) unit, based upon a production lot of ten (10) units.

7.1 Material:

The total material cost for the Mini-Fopp is $102.33 and for the Fopp-100 is $908.07, for a total of $1,010.40 for both models. These costs include the following:

A. Fopp-100

1. Raw Materials

| | |
|---|---|
| Aluminum | $ 39.35 |
| Bronze | 20.00 |
| Hot Rolled Steel | 2.90 |
| Phenolic | .40 |
| 303 Stainless Steel | 4.68 |
| 440C Stainless Steel | 20.00 |
| Delrin | .85 |
| TOTAL | $ 88.18 |

2. Purchased components - hardware, bearings, etc.

| | |
|---|---|
| Pneumatic components | $ 88.85 |
| Aero pneumatic right angle driver | 310.50 |
| Case and inserts | 104.10 |
| Lubricator | 32.02 |
| Wrench | 8.92 |
| Collet 32D Levin | 18.35 |
| Draw bar Levin | 36.00 |
| Hardware | 31.15 |
| TOTAL | $ 629.89 |

3. Outside processing

| | |
|---|---|
| Heat Treat | $ 5.00 |
| Passivate Stainless | 2.50 |
| Diamond Wheel Coating | 180.00 |
| Anodize | 3.00 |
| TOTAL | $ 190.50 |

B. Mini-Fopp

1. Raw Materials

| | |
|---|---|
| Aluminum | $ 4.84 |
| Brass | 2.36 |
| 440C Stainless Steel | 2.60 |
| Phenolic | .25 |
| Delrin AF | .65 |
| CN-705 Gasket | 1.50 |
| 40 DP., 70T. Timing | |
| Belt Pulley Stk. | 3.15 |
| Hot Rolled Steel | .16 |
| TOTAL | $ 15.51 |

2. Purchased Components

| | |
|---|---|
| Hardware | $ 20.07 |
| TOTAL | $ 20.07 |

3. Outside Processing

| | |
|---|---|
| Heat Treat | $ 6.00 |
| Anodize | 10.75 |
| Diamond Coating | 50.00 |
| TOTAL | $ 66.75 |

C. Material cost breakdown for both models

1. Total Raw Materials

$88.18 + $15.51 = $103.69 = 10.2% total material

2. Total Purchased Components

$629.89 + $20.07 = $649.96 = 64.3% total material

3. Total outside processing

$190.00 + $66.75 = $256.75 = 25.4% total material
NOTE: of this $256.75, $230.00 is for the diamond coating

D. Analysis:

If the production lot size is increased from 10 units to 100 units, reductions in the material cost would result as follows:

1. 40% reduction in raw materials due to elimination of cutting charges and price breaks for quantity buys for castings.

60% of $103.69 = $62.21

2. 30% reduction in purchased components due to quantity

70% of \$649.96 = \$454.97

3. Outside processing - 40% reduction in the cost of the diamond wheel and a 90% reduction in the other processing.

60% of \$230.00 = \$138.00
10% of \$ 26.75 = \$ 2.66
TOTAL \$140.66

4. The total material cost per unit for a 100 quantity lot would then be

\$62.21 + \$454.97 + \$140.66 = \$657.84 or 34.8% reduction

7.2 Production Set-Up Costs:

A. Tooling

\$1,402.50 is required for tooling to produce both models in a 10 lot quantity. Spreading this over the 10 units, it works out to \$140.25 for both models - \$50.05 for the Mini-Fopp and \$90.20 for the Fopp-100.

This tooling consists of six (6) vertical mill fixtures at \$522.50, two (2) drill-jigs at \$80.00, ten (10) lathe tools and fixtures at \$284.00, one (1) buttress tap at \$66.00, one (1) steel rule die at \$200.00, and one (1) sand cast pattern at \$250.00. All the above tooling is re-usable.

In order to produce at 100 quantity lot level, three (3) additional sand cast patterns at \$300.00 each and two (2) additional buttress taps at \$132.00 would be required. Thus the total tooling for the 100 quantity would be \$1402.50 plus \$1032.00 which equals \$2434.50. Spreading this over 100 parts reduces the tooling cost to \$24.35 to produce both models - \$13.29 for the Fopp-100 and \$11.05 for the Mini-Fopp.

B. Facilities and Equipment

Since the major components of both of the polishers have been designed as machined castings, for efficient production in the 50-100 quantity lot size, a machine shop with a minimum of 25,000 square feet of floor space would be a suitable facility for this production.

The following machine list is the minimum required for each level of production:

| Machine | Number of Each Machine | |
|---|---|---|
| | 10 Qty Lot | 100 Qty Lot |
| Vertical Mill<br>Bridgeport 2T or Equiv. | 2 | 4 |
| Vertical Mill<br>Bridgeport Series/CNC | 0 | 1 |
| Surface Grinder<br>Boyer-Schultz 1A618 w/Magnetic Chuck | 1 | 3 |
| Metal Cutting Cut-Off Saw 6" | 1 | 1 |
| Engine Lather w/3 Jaw, 4 Jaw<br>and Collets-Clausing 14 x 32 | 2 | 2 |
| Drill Press | 1 | 0 |
| Turret Drill Press<br>Burgmaster Model OB | 0 | 2 |
| Chucker Lathe<br>Harding E-AHC Model | 0 | 1 |
| or | | |
| Lathe, Engine NC | 0 | 1 |
| Assembly Benches 4' x 8' | 2 | 3 |
| Tool Post Grinder | 1 | 1 |
| Tool Post Grinder for Carbide | 1 | 1 |
| Surface Plate 2' x 2' | 1 | 1 |
| Height Gage w/Indicator .0001 Accuracy | 1 | 1 |
| Gage Blocks 0-1" .00005 Accuracy | 1 set | 1 set |
| Micrometer Set 0-6", .0001 Accuracy | 1 set | 1 set |
| Gage Pin Set .062" - 2.000" | 1 set | 1 set |
| Hardness Tester w/C-Scale | 1 | 1 |

7.3 Special Handling and Processing:

Special handling and processing is required for the fabrication of the diamond grinding wheels. The wheels must be flat within .0005 inch. This flatness is achieved by surface grinding. After grinding, the wheels must be oiled and polybagged separately to prevent scratching.

The diamond coater must also take special care to prevent scratching the significant surface. Crystalite Corporation provides the special diamond coating process. This process, utilizing an electro-plating process, metal bonds 1500 mesh diamond to the steel wheels. The associated processing costs are covered in section 10.1.B.3 of the contract.

7.4 Assembly Time:

The total assembly time for the Mini-Fopp is 0.5 hour/unit. This is broken down as follows:

1. 0.1 hour for the contact holder assembly
2. 0.4 hour for the final assembly per 070330-0000 drawing

The total assembly time for the Fopp-100 is 0.72 hours/unit. This is broken down as follows:

1. 0.37 hours/unit for mechanical assembly per 111230-0000 drawing.
2. 0.30 hours/unit for pneumatic assembly per 111230-000 drawing.
3. .05 hours/unit for assembly of the foam inserts into the case.

7.5 Fabrication Costs and 10.8 Manufacturing:

Fabrication and manufacturing labor hours are listed on Attachment #1, of the contract, Sheets 1 thru 4, under the column titled "Hours/Units". Fabrication labor hours by operation for each component are listed on Attachment #2, of the contract, Sheets 1 thru 37, under the columns titled "Set-Up Hours and Machine Hours" each.

The above Set-Up and Machine Labor Hours/Unit are based upon the 10 quantity lot. If the lot size is increased to 100 units, the set-up hours would be reduced from 21.385 to 2.14 hours/unit and the machining hours/unit would be reduced 50%

from 27.905 to 13.952 hours/unit. At a $20.00 burdened shop rate the cost/unit would be reduced from $985.80 to $321.84 (for both models).

7.6 Quality Control:

A quality control system, including an incoming inspection for raw materials, an in-process inspection, and a final inspection, is required for the economical manufacturing of these polishers. All inspection is based upon a 1.0 AQL. level per MIL-STD-105D.

The cost of this quality control system per unit (for both models) would be 11.7% of the fabrication shop rate. At $20.00/hour, this equates to $2.35/hour. Translating this to the 10 quantity lot size, the cost is $115.83/unit. At the 100 quantity lot, the cost would be $37.41/unit.

7.7 Overhead:

The following overhead breakdown would be typical of the job shop machine shop:

| Element | % of Total Burden | | $/Hour |
|---|---|---|---|
| 1. Indirect labor, wages & fringes | | 53.4% | 6.40 |
| A. Management & Supervision | 12.7% | | 1.54 |
| B. Inspection & Quality Control | 19.6% | | 2.35 |
| C. Secretary & Clerical | 11.2% | | 1.34 |
| D. Down Time | 8.3% | | .99 |
| 2. Supplies | | 26.7% | 3.20 |
| 3. Depreciation Machinery | | 1.55% | .18 |
| 4. Maintenance - Bldg & Machinery | | 2.78% | .33 |
| 5. Rent & Utilities | | 7.4% | .88 |
| 6. Purchasing & Accounting | | 8.0% | .96 |
| | TOTAL | 100% | $12.00 |

The variable overhead with respect to throughput would be down time at $.99/hour. This would be eliminated with higher throughput; thus the burden rate would become $11.00/hour.

7.8 Test Equipment

Standard measuring (QA) equipment is required for the production of these polishers. This is listed under Section 10.2B of the contract.

A functional test is performed on the finished assemblies for the final inspection. This is accomplished by grinding and polishing a ferrule and measuring the end surface finish and flatness. A profilometer is used for measuring the surface finish. A profilometer, such as a Federal Model AD-22 costing $1795.00, would be sufficient. A dial indicator, with .0001 inch graduations, is used to measure the surface flatness. It is a standard QA tool and costs approximately $100.00.

7.9 Additional Factors - MTBF, MTTR

The estimated MTBF would be ten (10) years for both models and the estimated MTTR would be five (5) years. The estimated MTBF and MTTR does not include the expected life of the diamond and lapping wheels. The life of these wheels will be use dependent. Consequently, replacement wheels should be stocked. Wheel life should be monitored to determine the wheel inventory level.

7.10 Production Yield Data

The production yield would be expected to be 95% in small lots and 90% in large production lots. Obviously, this is dependent upon the skill of the machinists and supervision. The above yield estimates are based upon an above average machine shop skill level. The AQL level, as stated in Section 10.6, of the contract is 1.0 MIL-STD-105D.

## 8.0 SUMMARY

Manufacturing processes and techniques were established and properly documented so that high volume manufacturing of fiber optic cable termination polishers can be properly accomplished.

The goals and objectives established in the contract were satisfactorily met and the delivered polishers are now being field tested to determine their effectiveness and applicability to their intended purpose.

One field test conducted to date indicated that the termination polish obtained with the unit was of high quality and better than required for the application.

The complete set of documents pertaining to the manufacturing process for the portable air driven variable speed fiber optic termination polisher is in file and available to qualified users.

## 9.0 APPENDIX SUMMARY

Appendices A, B, C, and D included herein, outline the Quality Assurance inspections deemed necessary to obtain a fiber optic cable polisher that will satisfy the flatness and waviness requirements of fiber optic cable terminations.

These procedures outline the actual steps utilized by the contractor to demonstrate the ability of the fiber optic cable polisher to satisfy the requirements of the contract.

Future contracts may not be required to adhere strictly to these procedures; however, similar procedures shall be developed for each particular contract.

APPENDIX A

QUALITY CONTROL

FIRST ARTICLE INSPECTION PROCEDURE FOR CONTRACT N66001-78-C-0035

(PORTABLE AIR DRIVEN VARIABLE SPEED FIBER OPTIC CABLE TERMINATION POLISHER)

1.0 PURPOSE

The procedure will provide a basis for the inspection and testing to be performed on the First Article unit to demonstrate its capability of meeting the requirements of this contract, N66001-78-C-0035.

2.0 GENERAL

2.1 The First Article approval will be per section J.3 of N66001-78-C-0035 contract.

2.2 Number of units involved: one (1)

2.3 Schedule and Location of Accomplishment:

Test Dates: 5 June 78 thru 15 June 78

Location: ITTCE
666 East Dyer Road
Santa Ana, California 92702

First Article Inspection Report due 29 June 78.

3.0 SUPPORT EQUIPMENT REQUIRED FROM THE GOVERNMENT:

Fifty (50) terminated F.O. ferrules per NOSC Dwg. No. 000 6509 and DOD-STD-1678 less steps 7, 8, and 9 Sec. 4.4, Procedure IV.

4.0 PROCEDURES:

4.1 Verification of Documentation and Manufacturing Methods:

All fabricated components and standard purchased components will be received and inspected per ITTCE Quality Control Procedure (QCP) 501 attachment 1.

The unit will be assembled at ITTCE and the assembly inspected per QCP 601 & QCP 604, attachments 2 and 3 respectively.

4.2 Examination of the Product:

The unit will be inspected 100% to the drawing requirements for completeness, workmanship and configuration conformance. Special attention will be given to the following:

A. Run-out of grinding disk mounting surface.

B. Perpendicularity of ferrule holding device to grinding disk mounting surface.

C. Weight.

4.3 Verification of Performance:

A. Low temperature, low humidity environmental functional test: The uncased unit will be acclimated for 24 hours at $5^{0}$C and 10% RH in an ITTCE environmental chamber. Upon removal the unit will be used to grind and polish ten (10) terminated, NOSC Dwg No. 000-6509, standard end ferrules. Performance will be verified with ten (10) of ten (10) ground and polished ferrules, meeting section F.3.2.1.14 of N66001-78-C-0035 contract; inspected as follows:

a. Two surface finish measurements will be taken on the stainless steel face of the ferrule, using a <u>Gould</u> Model 21-1350-00 profilometer. The measurements will be made on two different non-intersecting cordial lines, .050$\pm$.015 inch long. Both measurements must be 10 micro-inches or better.

b. One waviness measurement will be taken on the stainless steel face of the ferrule using a <u>Bendix</u> <u>Portaron</u> roundness and geometry system. The measurement will be taken from a .093 inch Dia. ring on the stainless steel face, to an accuracy of $\pm$.00005 inch. The waviness must be within .001 inches.

c. A photograph will be taken using an optical microscope, to verify the polish of the glass bundle per DOD STD 1678, dtd 30 Nov. 1977.

B. High temperature, high humidity environmental functional test: The above test 4.3.A will be repeated at $80^{o}C$ and 100% RH, condensing.

C. Salt Atmosphere:
The unit will be subjected to a 48 hour salt spray test per MIL-STD 202, Method 101, Test Condition A. Upon removal from the cabinet, the unit will be used to grind and polish ten (10) terminated ferrules as in 4.3.A above. Verification will be as in 4.3.A above.

4.4 Verification of Maintainability

A. A timed disassembly and assembly test will be performed. Verification will be per Section F3.2.3.1 of N66001-78-C-0035 contract.

B. A timed removal and replacement of the abrasive disk will be performed. Verification will be per Section F3.2.3.2 of N66001-78-C-0035 contract.

APPENDIX B

QUALITY CONTROL

RECEIVING INSPECTION PROCEDURE

1.0 PURPOSE

To outline and define the function and responsibilities for the receipt, inspection and test of material, parts, and sub-assemblies furnished by suppliers.

2.0 GENERAL

Incoming material may be raw material - bar stock, plastic compound, rubber compound and ingots - from which ITTCE products will be fabricated, inside processing components, or outside processing product. (Reference QCP-502 for lot identification and traceability requirements).

3.0 PROCEDURE

3.1 Receiving

A. Receive all incoming shipments and review all paperwork to assure shipment consists of parts and/or material as called for on ITTCE purchase order.

B. Keep all like bar stock material separate by vendor and type, bundled and strapped.

C. Verify that required paperwork is complete including purchase order, certifications, drawings, packing slip and routing, as applicable, before releasing. If there is no certification, notify Purchasing and hold material.

D. Verify correct drawing revision per purchase order.

E. Verify count per packing slip quantities. If count is short on OSP goods (S.O. # exists), create a split.

F. Maintain file of completed purchase orders.

G. Deliver tools and gages to Tool Inspection and/or Gage Inspection for acceptance.

H. Submit repaired or reworked material with a copy of the purchase order indicating the original rejection and a copy of the Product Discrepancy Report per the PDR number on the supplier's packing slip.

I. Move all incoming material, parts, or sub-assemblies from Receiving to Receiving Inspection.

3.2 Receiving Inspection

A. Verify that the material, purchase order, packing slip, and certification are all in agreement.

B. Verify that certification fulfills the purchase order requirements.

C. Verify that the print revision conforms to revision on the routing and purchase order.

D. Verify that Raw Material Identification Number (RMI No.) is on vendor paperwork when vendor has processed ITTCE supplied material and record RMI number on two (2) copies of the routing; the Accounting copy and one other copy.

E. When material requires Material Lab Analysis, send cut off from each such lot with the paperwork to the appropriate lab.

F. Where required, pull the applicable Parts History Card and select the applicable Inspection Instruction.

G. Determine correct sample size from the applicable Sampling Plan for the specified AQL on the Inspection Instruction or Specification.

H. Verify that each gage being used has a current calibration sticker.

I. Select the sample size at random from the lot and inspect each unit in the sample for the applicable characteristics.

J. Place acceptance stamp on the purchase order and two (2) copies of the shop routing opposite the applicable sequence when the lot is acceptable. Record Inspection results on Parts History Card as required by Paragraph 5.0.

K. When parts are going directly to the Stockroom, stamp two copies of the shop routing with the "OK for Stock" stamp, entering the required information. If there are insufficient copies of the shop routing, prepare "OK for Stock" tag or reproduce second stamped copy (not Accounting copy) for each of the remaining containers in the lot.

L. Assign Raw Material Identification number (RMI No.) per QCP 502 and enter number on shop routings and "OK for Stock" tag (if applicable), the certification, and any other applicable paperwork.

M. Move accepted lots to the "Outgoing Material" area.

N. Attach packing slip to yellow copy of purchase order for each accepted lot, then place in designated tray for accounting to pick up.

O. Stamp and date W.I.P. ticket for each accepted lot. Add reject stamp, date, and PDR number on one copy of routing for each rejected lot. Place rejected routing copy in designated tray for P.C. pickup.

P. Complete Product Discrepancy Report (PDR) per QCP 701 and QCP 702 for a rejected lot.

Q. Place rejected material on the designated HOLD shelf with the PDR and all applicable paperwork for disposition by PMR.

R. When material is to be returned to vendor for credit/replacement or rework, submit material and all documentation to Receiving for processing. Place green copy of PDR in parts history file. PDR must be signed by Purchasing approving RTV.

S. Record inspection data including part number, vendor number, packing slip number, purchase order number, lot size, sample size, RMI number, and status on the Receiving Inspection Daily Report (form ITTC 5025). The reports are forwarded daily to Quality Assurance office for processing and filing. Enter data in the applicable Parts History File.

3.3 Vendor Certification

A. As required by the purchase order, subcontractors submit certifications with each lot of material, part, or sub-assemblies which include data from physical and chemical tests and/or environment test results, when applicable.

B. When the certification of conformance is included on the packing slip or the packing slip states that certification of conformance is on file at the vendor facility, a copy of the packing slip is filed in the Vendor Certification file.

- The use of the packing slip as a certification copy is not acceptable where the purchase order specifically requires separate copies of the certification.

C. Certification (minimum of one) are placed in the Vendor Certification file for a period of five (5) years.

3.4 Verification of Certifications and Test

A. Certified physical and chemical test reports supplied by the raw material supplier or other competent laboratory is accepted in lieu of vendor's shipment certification.

B. Samples from the first five (5) and subsequently every fifth (5th) lot from each supplier for each type of raw material will be submitted to the ITTCE laboratory or a certified OSP laboratory for material analysis to verify the applicable certification.

- A sample disc shall be melt-formed from a billet out of each heat lot. Sample is submitted to lab for spectograph analysis.

C. If one lot of non-conforming material is received, then each subsequent lot of the same type of material from the same supplier will be tested by the lab until three (3) consecutive lots of acceptable material have been received. Then every fifth (5th) lot will be tested.

D. Samples from incoming lots of rubber compound material and/or components of silicone and fluorosilicone material are forwarded to the Quality In-Process Laboratory for testing per special Inspection Instructions.

E. Additional tests are performed when required by drawing or specification, or when required by Quality Engineering to maintain quality requirements of applicable specifications.

F. The Raw Material Log indicates which lots have been verified.

G. The RMI No. is assigned prior to sending samples to be tested to verify vendor certification. Material is controlled until test results are received. This permits test reports to be identified with the RMI No.

H. When notified of test failure, a PDR is initiated and the material is placed on the HOLD shelf for disposition by PMR.

3.5 Raw Material Control

A. Prior to issue to the Manufacturing areas, color code the accepted raw material in accordance with the "Standard Color Codes for Raw Materials." When it becomes necessary to issue a partial rod/bar, cut only from unidentified end, then color code one end of cut piece. The codes are listed in Section 6.0 of this procedure.

These color codes are for identifying material in the Manufacturing areas.

Note: Material in a box from which no issue has been made will not require color coding; the raw material I.D. tag on container identifies the material.

B. Attach the Raw Stock rag, form ITTC 1634, to material as follows:

- For material stored outside, place the Raw Stock tag in a plastic envelope, seal or staple, and then attach to material, one to each bundle or container.
- For material stored inside the plant, secure one tag to each bundle of material or container.

## 4.0 SUPPLIER SOURCE

4.1 ITT Cannon Supplier Source Inspection, when used, does not relieve the vendor of his basic Quality Control responsibilities, nor does it necessarily indicate final acceptance of the product or services.

4.2 Final acceptance of vendor furnished materials is made by Receiving Inspection at ITTCE.

## 5.0 PARTS HISTORY FILE

A file is maintained for each part number received. Within each file, there is a separate record for each vendor supplying the part showing date inspected, job lot number, quantity, inspection results, and PDR number, if applicable, of each lot submitted. Any special instructions for the inspection of this part are included in this file.

APPENDIX C

QUALITY CONTROL

GENERAL INSPECTION PROCEDURE

1.0 PURPOSE

To describe the general methods and responsibilities of Inspection personnel in determining that materials, processed parts, and completed assemblies are in accordance with applicable specifications and drawing requirements.

2.0 REFERENCE DOCUMENTS

MIL-Q-9858A/NHB5300.4 (1CO

MIL-STD-105

Quality Control Instructions (QCI)

Acceptance Limits (AL)

Quality Control Procedures (QCP)

3.0 GENERAL

3.1 Quality Assurance policies and procedures are based on a single standard inspection plan and meet or exceed minimum requirements of MIL-Q-9858A and NHB5300.4 (1C).

The following inspection and Quality Control procedures are maintained on all products manufactured at this facility:

A. The minimum standards of quality are provided for in Government contracts.

B. All materials and supplies varying from the drawing or specification requirements shall be handled in accordance with the material review procedures. Disposition by the Material Review Board shall be final and applicable to the entire lot under consideration.

C. All procedures and operations are subject to the surveillance of the Government Quality Assurance Representative.

D. Necessary measuring and testing equipment will be available for use by the Government representative for determining conformance of submitted lots. When required, personnel will be available to operate or verify the equipment condition and/or accuracy.

E. Requests for Government Source Inspection from outside this facility will be coordinated with DCAS through the Government Quality Assurance Representative.

F. Government-owned and contractor-owned materials will be kept separate.

G. Individual customer quality requirements above and beyond standard requirements are specified on the customer purchase orders. These requirements are transferred to applicable ITT Cannon documents.

3.2 Inspectors have the authority and responsibility to accept or reject material at all times. In the event any material or items prove defective to an Inspector, regardless if the part has been previously approved by another Inspector, the item must be withheld and Quality Assurance Supervision consulted.

4.0 PROCEDURE

4.1 Inspection Tools

A. The minimum tools (identified and registered by Gage Control) an Inspector is required to have available are: 1" micrometer and dial caliper.

B. Company tools maybe obtained from the Gage Crib at the beginning of each shift. These must be returned to the Gage Crib at the end of each shift.

C. Company tools on a permanent loan basis to an inspection station must be reviewed by the Inspector before use for proper calibration identification.

D. Tools found with past due calibration or in need of repair must be returned to the Gage Crib for recalibration or repair as required.

E. Personally owned tools must be maintained in good working order at all times. These are recalled for calibration on a scheduled basis with records of such on file in the Gage Crib.

F. Selection of the proper tool is the responsibility of the Inspector. If there is any doubt, the Quality Assurance Supervisor should be contacted to insure the proper tool is used.

4.2 Inspection Stamps

A. Each Inspector is issued Acceptance and Rejection stamps. (Ref. QCP 105 - Stamp Control)

B. Inspectors shall not loan their inspection stamps to any other person nor leave them unattended.

C. A master list of all issued stamps is maintained in the Quality Assurance office and audited yearly.

4.3 Inspection Stations

A. Inspection stations are established as required, but are normally located in the Receiving, In-process, and Final Assembly areas.

B. Each normal location is not necessarily limited to one inspection station.

4.4 Acceptance Characteristics & Criteria

A. Product characteristics are separated in three (3) major classifications:

a. Critical Characteristic - This is a deviation which may result in unsafe conditions or malfunction of the end product. This classification requires 100% inspection with no allowable defects.

b. Major Characteristic - This is a characteristic which could result in failure or materially reduce the usability of the part in the end product. As a result, while sampling is permitted, quality levels must be high.

c. Minor Characteristic - This characteristic is one in which a variation does not materially reduce the usability of the unit or product for its intended purpose, or it is a departure from established standards having no significant bearing on the effective use or operation of the unit. A 4.0 AQL is normally used for this characteristic.

B. Inspection Criteria for Acceptance:

a. For inspection of product, the Inspector uses a combination of the following documents:

Cannon component/assembly drawings

Workmanship Standards/Acceptance limits

Cannon production routings

Quality Control Instructions

Quality Control Procedures

Acceptance Test Procedures

Applicable Engineering Specifications

b. Quality Supervision will be contacted for clarification and explanation on any characteristic or instruction that is not completely understood by the Inspector.

4.5 Sampling Inspection Method

A. Each lot of material, parts, or assemblies is submitted to Inspection for sampling inspection.

B. Each lot comprises a homogeneous order - all parts being of the same structure or material, or class of assembly submitted to Inspection at one time.

C. The Inspector selects the proper sampling table in accordance with the applicable Quality Control Instruction and determines the sample size to be inspected.

D. The Inspector takes samples at random from the total quantity submitted. When more than one container is involved, parts must be selected from each tray or box.

E. All parts in the sample are inspected 100% in accordance with the applicable Quality Control Instructions, Acceptance Limits and Procedures.

F. The Inspector determines whether the acceptance number has been exceeded. If it has not been exceeded, he accepts the lot. Any non-conforming items in the sample are withheld for disposition, and the acceptable items are returned to the lot.

G. When the number of discrepant items is equal to or exceeds the rejection number in the sampling table, the Inspector withholds the entire lot and initiates a Product Discrepancy Report (PDR). Rejected lots are segregated and moved to the applicable hold area with related paper work pending disposition by Material Review Board.

4.6 Indication of Inspection Status During Manufacture

A. Shop Routing

All in-process articles are identified by means of this form, which lists all manufacturing and inspection operations. The status of the items is indicated by Inspection stamps opposite the last inspection operation performed.

All items are accompanied by a Shop Routing which must show acceptance of all Inspection operations and/or an "OK for Stock" card before they can be accepted into stock.

B. Assembly Order

The block stamp on the reverse side of the Assembly Order, listing all operations or tests to be performed on subassemblies and/or assemblies, must indicate completion and acceptance. If this is not evident, the order will be returned to Production without further inspection.

4.7 Recording of Inspection Data

A. Upon completion of inspection, the Inspector enters the pertinent data on the applicable inspection report form, Set-up and Patrol or Daily Inspection Report, including, where required, part number, lot size, sample size, number of discrepant parts, if any, rejection report number (PDR), and cause code of discrepancy.

B. All inspection data reports are forwarded weekly to Quality Engineering for analysis, compilation of reports, and filing. They are maintained in file for two (2) years except Final Inspection (4 years).

C. Completed rejection reports (PDR's) are forwarded to Quality Assurance and Accounting per QCP 701.

4.8 Special Customer Requirements

A. Lot Control

Requirements for special lot control are specified on the shop routing and identified on the assembly order.

Adherence to lot control procedures is mandatory and each Inspector insures that all requirements are met before proceeding with further inspection.

B. Acceptance Testing to Customer Requirements

When final inspection has been completed on a customer order requiring special acceptance testing, the Final Inspection Supervisor will forward the lot, together with all related paperwork, to the Quality Acceptance Lab. The Customer Source Representative is notified if he is to witness testing. When testing is completed and the applicable form signed, the parts with the paper work are forwarded to Packaging.

# APPENDIX D

QUALITY CONTROL

SUB-ASSEMBLY, FINAL INSPECTION, AND TEST

1.0 PURPOSE

To describe the methods and responsibilities of Sub-Assembly and Final Inspection.

2.0 REFERENCE DOCUMENTS

| | |
|---|---|
| QCP 601 | General Inspection Procedure |
| QCI's | Quality Control Instructions |
| QCP 701 | Non-Conforming Material Control |
| QCP 702 | Instructions for Completing PDR |
| QCP 204 | Quality Assurance Testing |

3.0 GENERAL

3.1 Sub-Assembly and Final Inspection is performed in accordance with QCP 601, General Inspection Procedure, para. 4.4 and 4.5, and any applicable Quality Control Instruction and Inspection document.

3.2 Non-conforming items are processed per QCP 701 and 702.

4.0 PROCEDURE

4.1 Inspection

A. Select lot to be inspected, using current production priority system.

B. Review paper work package verifying that all documents, including I-Master (Form 117) or Shop Routing (Form 349), Parts List, Print, and Flimsy, are available.

C. Check I-Master/Routing for special instructions. If there are none, use instructions for normal inspection, selecting correct sampling table.

D. Check I-Master for lot control requirements. If required, verify that all necessary information is recorded on reverse side of I-Master. If incomplete, do not proceed with inspection, but notify your Supervisor.

E. Determine which gages, equipment, etc., are needed and obtain them.

F. Determine the correct sample size and select samples <u>at random</u> from lot.

G. Perform inspection on 100% of the samples using the applicable Inspection Instruction, Print, and any other Inspection document referenced. Check <u>all</u> characteristics listed on the Inspection Instruction.

H. Stamp I-Master on left side of amount column with acceptance stamp if lot is <u>acceptable</u> and record date.

I. Reject the lot if the defects exceed the acceptance number, initiate a PDR per QCP 701, 702, record the PDR number with blue pencil on the face of I-Master and place rejection stamp on reverse side. Place parts with paper work and PDR on reject rack for further processing. When discrepancy can be reworked within the assembly area, a short form PDR (RR) is initiated in lieu of the PDR.

J. Inspect re-submitted lots for rejected characteristics only.

K. Perform 100% visual inspection when specified on I-Master or when authorized by Quality Assurance Supervision.

L. Record inspection information on the Daily Inspection Report (Form 1658) and forward to Quality Assurance Supervision daily.

M. Place customer orders requiring acceptance testing after Final Inspection on rack in Assembly set aside for this purpose. These orders are moved to the Quality Acceptance Laboratory by Material Handling.

4.2 Quality Acceptance Laboratory

A. Review customer orders for acceptance test requirements. Verify test sample quantities when applicable. Notify Quality Engineering of any errors.

B. Review applicable approved Acceptance Test Procedure.

C. Verify that paper work with parts include all required information and evidence of Final Inspection.

D. Perform acceptance tests in accordance with Acceptance Test Procedure and/or customer requirements. Record results and test time in log. Stamp log number on test report.

E. Complete Test Report on applicable form. Send parts, applicable paper work and Test Report to cognizant Inspector for final acceptance after test.

F. Place parts on Hold shelf if tests or shipments are to be delayed.

G. If failures occur during testing, set failed units aside and continue testing. Complete PDR and place with failed units in HOLD area for CMR disposition. Accepted units continue per para. E. above.

H. Initiate paper work for further testing to be performed by the Product Evaluation Laboratory or an outside laboratory and forward parts with applicable paper work and instructions for completion of required tests.

I. Consolidate test reports when all testing is completed, attach to paper work and forward with parts to Final Inspector for final acceptance after test.

4.3 Intermateability of Connectors

The intermateability of connectors is verified by the performance of periodic requalification tests as required by the Military Specifications. Test reports are on file.

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